

## Verification of Translation

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1. I am familiar with the Japanese and English languages.
2. I have read the attached translation into Japanese Patent Application No. HEI9-172339 filed on June 27, 1997 and the attached translation is a accurate translation of the Japanese-language original document.

Executed at Otsu-shi, Shiga-ken this 17th day of March, 2000.

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[Title of the invention] A method for producing a plasma display panel

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[Title of the invention] A method for producing a plasma display panel

[Claims]

[Claim 1] A method for producing a plasma display panel, in which a glass substrate is coated with three fluorescent pastes respectively containing a fluorescent powder emitting light of red, green or blue discharged from a paste applicator with outlet holes, in stripes on the spaces between the respectively adjacent partitions formed on the substrate, and the pastes are burned to form a fluorescent face, characterized in that the paste applicator used satisfies the following formula:

$$L/D = 0.1 \sim 600$$

where L is the length of the outlet holes, and D is the diameter of the outlet holes.

[Claim 2] A method for producing a plasma display panel, according to claim 1, wherein D is 80 to 400  $\mu\text{m}$ .

[Claim 3] A method for producing a plasma display panel, according to claim 1 or 2, wherein L/D is 1 to 250.

[Claim 4] A method for producing a plasma display panel, according to any one of claims 1 through 3, wherein the outlet holes are straight holes or nozzles or needles respectively provided in a flat plate.

[Claim 5] A method for producing a plasma display panel, according to any one of claims 1 through 4, wherein the paste

applicator and/or the glass substrate is driven to travel in parallel to the partitions formed on the glass substrate.

[Claim 6] A method for producing a plasma display panel, according to any one of claims 1 through 5, wherein the paste applicator has two or more outlet holes per color.

[Claim 7] A method for producing a plasma display panel, according to any one of claims 1 through 6, wherein the fluorescent pastes used have a viscosity of 0.1 to 50 Pa·s.

[Claim 8] A method for producing a plasma display panel, according to any one of claims 1 through 7, wherein the fluorescent powders have a cumulative average grain size of 0.5 to 15  $\mu\text{m}$  and a specific surface area of 0.1 to 5  $\text{m}^2/\text{cc}$ .

[Claim 9] A method for producing a plasma display panel, according to any one of claims 1 through 8, wherein the fluorescent pastes are discharged at a pressure of 50 to 1000 kPa.

[Detailed description of the invention]

[Technical field of the invention]

The present invention relates to a new method for producing a plasma display panel. The plasma display panel of the present invention can be used for wall mounted television sets and information displays.

[Prior arts]

The conventionally known methods for producing plasma display panels include screen printing. Especially for

forming fluorescent materials of plasma displays, screen printing has been frequently used.

Japanese Patent Laid-Open (Kokai) No. 6-5205 proposes to use sand blasting after screen printing, and Japanese Patent Laid-Open (Kokai) No. 5-144375 proposes to effect screen printing after coating with a crosslinking agent. Both the techniques use screen printing.

However, screen printing does not allow a highly precise pattern to be formed disadvantageously since the screen is deformed by repeated printing, and also in view of control such as washing of the screen, screen printing cannot be said to be suitable for mass production.

The use of lithography is also practiced as a method for obtaining a highly precise pattern. However, in this case, since the respective fluorescent material layers of red, green and blue must be formed, the respective steps of coating, exposure, development, drying, etc. must be repeated three times for the colors, and after full face coating with the respective colors and exposure, unnecessary portions must be removed by development, to wastefully consume the fluorescent powders. If they are recovered for reproduction, the cost is raised. Furthermore, there is also a problem that since the full face is coated with the respective colors, the overlying colors can remain after development, to cause color mixing.

It is also proposed to eject a fluorescent paste from the tip of an ink jet nozzle, for forming a fluorescent material layer. However, in the case of ink jet, since the fluorescent paste is ejected by a piezoelectric device, etc., the viscosity of the fluorescent paste must be kept at less than about 0.02 Pa·s, and so the amount of the fluorescent powder in the paste cannot be increased. Therefore, the thickness of the formed fluorescent material layer is too thin disadvantageously.

( There is another problem that since the ink jet nozzle must be small in diameter, it is clogged with the fluorescent powder.

[Problems to be solved by the invention]

The object of the present invention is to provide a method for producing a plasma display panel free from the above disadvantages, particularly a method for producing a plasma display panel which allows fluorescent material layers to be formed simply at high accuracy.

( [Means for solving the problems]

The object of the present invention can be achieved by a method for producing a plasma display panel, in which a glass substrate is coated with three fluorescent pastes respectively containing a fluorescent powder emitting light of red, green or blue discharged from a paste applicator with outlet holes, in stripes on the spaces between the respectively adjacent partitions formed on the substrate, and the pastes are burned



to form a fluorescent face, characterized in that the paste applicator used satisfies the following formula:

$$L/D = 0.1 \sim 600$$

where L is the length of the outlet holes, and D is the diameter of the outlet holes.

[Embodiments of the invention]

The present invention relates to a method for coating a glass substrate 2 having electrodes 1 and partitions 3 formed on it as shown in Fig. 1, partially with fluorescent pastes, particularly a method for forming a red fluorescent material layer 4, a blue fluorescent material layer 5 and a green fluorescent material layer 6 as shown in Fig. 2, by coating the substrate with fluorescent materials emitting light of any of three principle colors, red, blue and green in stripes.

Since three stripes of red (R), blue (B) and green (G) form one pixel line, they must be formed in repetition of RGB or RBG.

For forming the respective fluorescent material layers, at first the three paste applicators respectively with one outlet hole provided for discharging any of the three colors of R, G and B respectively are driven to travel in parallel to the partitions and/or the glass substrate is driven to travel, while the fluorescent pastes of the respective colors are discharged onto the predetermined spaces between the respectively adjacent partitions, for coating. As a more efficient method, a paste applicator with two or more outlet

holes at predetermined coating intervals for one color (the center distance between the respectively adjacent outlet holes for each color is three times the pitch of the partitions) can be used for simultaneously discharging from the plurality of outlet holes for coating of each color.

The paste applicator used in the present invention satisfies the following formula:

$$L/D = 0.1 - 600$$

where L is the length of the outlet holes, and D is the diameter of the outlet holes.

If L/D is smaller than 0.1, the outlet holes are insufficient in strength and likely to be deformed, and the fluorescent pastes are discharged unstably. For example, if the fluorescent pastes used have a viscosity of 10 Pa·s or less, they naturally drip, making it difficult to control the coating. If L/D is larger than 600, the length is too large compared to the inner diameter of the outlet holes, making the pressure loss of the outlet holes larger. In this case, the fluorescent pastes must be discharged at a higher pressure. Furthermore, it is difficult to maintain, for example, wash the outlet holes, posing a problem in practicality. A preferable range is 1 to 250.

The diameter (D) of the outlet holes must be decided with the pitch of partitions taken into account, and must be larger than the grain size of the fluorescent powders. It is

preferable that the diameter is 80 to 400  $\mu\text{m}$  for stable discharge of fluorescent pastes, considering the grain size distribution of the fluorescent powders and some cohesion.

The outlet holes of the paste applicator used in the present invention can be straight holes formed in a flat plate. It is preferable that the outlet holes are nozzles tapered as paste passages from the flat plate (Fig. 6), since paste clogging is hard to occur. It is also preferable that the outlet holes are hollow needles driven in a flat plate (Fig. 7), since the paste applicator is unlikely to be contaminated.

For coating, it is preferable that the distance between the tops of the partitions and the tips of the outlet holes of the paste applicator is kept at 0.01 to 2 mm, when the fluorescent pastes are discharged at a constant flow rate for coating the spaces between adjacent partitions while the paste applicator is driven to travel at a constant speed and/or the glass substrate is driven to travel. A more preferable distance range is 0.03 to 1 mm. Coating with this distance kept allows the fluorescent pastes to be poured onto the spaces between adjacent partitions while their contact with the tops of the partitions is avoided.

It is preferable that the fluorescent pastes used in the present invention have a viscosity of 0.1 to 50 Pa $\cdot$ s. A more preferable range is 1 to 30 Pa $\cdot$ s. The pastes with the viscosity

kept in this range allows better formation of fluorescent material layers.

For stable discharge of the fluorescent pastes for coating the spaces between the respectively adjacent pastes, it is preferable that the discharge pressure is 50 to 1000 kPa. If the pressure is smaller than 50 kPa, stable pressure control is difficult, and if larger than 1000 kPa, the pressure source and the sealing of pipe connections become costly.

It is preferable that the fluorescent paste consists of a fluorescent powder, and the ingredients to be evaporated or decomposed to be removed by the drying and burning after coating. In this case, a fluorescent material layer composed of a fluorescent material only can be formed after burning. The fluorescent paste can be, for example, a composition consisting of a fluorescent powder, organic dispersing agent, water soluble organic binder and water, or a composition consisting of a fluorescent powder, organic binder and organic solvent, or a composition with an organic dispersing agent added to said composition, etc.

If the composition is made photosensitive, patterning by photolithography can be applied. This is effective for removing the fluorescent materials formed on the tops of the partitions and other unnecessary portions than the spaces between the respectively adjacent partitions. The coated substrate is exposed through a photomask, so that the pastes in the exposed

portions may be made soluble or insoluble in the developer, and the unnecessary portions are removed in the development step, to form the fluorescent material layers of the respective colors.

The fluorescent powders used in the present invention are not especially limited. For example, those emitting light of red include  $Y_2O_3:Eu$ ,  $YVO_4:Eu$ ,  $(Y, Gd)BO_3:Eu$ ,  $Y_2O_3S:Eu$ ,  $g-Zn_3(PO_4)_2:Mn$ ,  $(ZnCd)S:Ag+In_2O_3$ , etc. Those emitting light of green include  $Zn_2GeO_2:Mn$ ,  $BaAl_{12}O_{19}:Mn$ ,  $Zn_2SiO_4:Mn$ ,  $LaPO_4:Tb$ ,  $ZnS:Cu, Al$ ,  $ZnS:Ag, Cu, Al$ ,  $(ZnCd)S:Cu, Al$ ,  $Zn_2SiO_4:Mn, As$ ,  $Y_3Al_5O_{12}:Ce$ ,  $CeMgAl_{11}O_{19}:Tb$ ,  $Gd_2O_2S:Tb$ ,  $Y_3Al_5O_{12}:Tb$ ,  $ZnO:Zn$ , etc. Those emitting light of blue include  $Sr_5(PO_4)_3Cl:Eu$ ,  $BaMgAl_{14}O_{23}:Eu$ ,  $BaMgAl_{16}O_{27}:Eu$ ,  $BaMg_2Al_{14}O_{24}:Eu$ ,  $ZnS:Ag+red$  pigment,  $Y_2SiO_3:Ce$ , etc.

Furthermore, the present invention allows the use of rare earth element tantalate fluorescent materials in which at least one matrix forming rare earth element selected from yttrium (Y), gadolinium (Gd) and lutetium (Lu) is substituted by at least one element selected from a group consisting of thulium (Tm), terbium (Tb) and europium (Eu). A preferable rare earth element tantalate fluorescent material is europium activated yttrium tantalate represented by composition formula  $Y_{1-x}Eu_xTaO_4$  (where x is approximately 0.005 to 0.1). A preferable red fluorescent material is europium activated yttrium tantalate, and a preferable green fluorescent material is terbium activated

yttrium tantalate represented by composition formula  $Y_{1-x}Tb_xTaO_4$  (where x is approximately 0.001 to 0.2). A preferable blue fluorescent material is thulium activated yttrium tantalate represented by  $Y_{1-x}Tb_xTaO_4$  (where x is approximately 0.001 to 0.2).

Further preferable green fluorescent materials include a manganese activated zinc fluorescent material ( $Zn_2SiO_4:Mn$ ) with an average grain size of 2  $\mu m$  to 8  $\mu m$  activated by 0.2 wt% to less than 0.1 wt% of manganese based on the weight of zinc silicate ( $Zn_2SiO_4$ ) matrix, and a manganese activated zinc silicate fluorescent material represented by general formula  $(Zn_{1-x}Mn_x)O \cdot \alpha SiO_2$  (where  $0.01 \leq x \leq 0.2$  and  $0.5 < \alpha \leq 1.5$ ).

The grain size of the fluorescent powders used in the above is selected, considering the line width, inter-line space and thickness of the fluorescent material layer pattern to be prepared. It is preferable that the powders are 0.5 to 15  $\mu m$  (especially 0.5 to 6  $\mu m$ ) in cumulative average grain size and 0.1 to 5  $m^2/g$  in specific surface area. It is more preferable that the grain size is 1 to 6  $\mu m$  and that the specific surface area is 0.5 to 4  $m^2/g$ . If the grain size and the specific surface area are in these ranges, the clogging of the outlet holes is unlikely to occur, and stable discharge can be effected, to provide a highly precise pattern. Furthermore, the fluorescent materials are higher in luminous efficiency and longer in life preferably. If the grain size is less than 0.5

$\mu\text{m}$  or the specific surface area is more than  $5 \text{ m}^2/\text{g}$ , the powders are too fine, and are likely to cohere. In this case, in the patterning according to photolithography, light is scattered during exposure, and non-exposed portions are likely to be photoset. So, extra fluorescent materials are likely to remain in the non-exposed portions at the time of development, not allowing a highly precise pattern to be obtained. Furthermore, the fluorescent materials decline in luminous efficiency and life.

As for the form of the fluorescent powders, polyhedral grains can be used, but it is preferable that the powders are not cohesive. It is more preferable that the powders are spherical grains since the clogging of the outlet holes is unlikely to occur, and since stable discharge can be effected and furthermore since the influence of scattering during exposure can be lessened in the case of patterning by photolithography. It is preferable that spherical grains account for 80% or more in the fluorescent powder in the number of grains. It is more preferable that spherical grains account for 90% or more. If spherical grains account for less than 80% in number, it is difficult to obtain a highly precise pattern, because of the influence of scattering by the fluorescent powder at the time of exposure to ultraviolet light. To measure the spherical grain percentage, the fluorescent powder is photographed at 300 times by an optical microscope, and the

number of countable grains is counted, to calculate the rate of spherical grains as the spherical grain percentage.

The organic component used in the present invention contains an organic binder, solvent, and, as required, such additives as a dispersing agent, plasticizer and leveling agent.

The organic binders which can be used here include, for example, (poly)vinyl butyral, (poly)vinyl acetate, (poly)vinyl alcohol, cellulose polymers (e.g., methyl cellulose, ethyl cellulose, hydroxyethyl cellulose, methylhydroxyethyl cellulose), polyethylene, silicone polymers (e.g., (poly)methylsiloxane, (poly)methylphenylsiloxane), polystyrene, butadiene/styrene copolymer, (poly)vinylpyrrolidone, polyamides, high molecular polyesters, ethylene oxide-propylene oxide copolymer, polyacrylamide, and various acrylic polymers (e.g., sodium polyacrylate, (poly) lower alkylacrylates, (poly) lower alkylmethacrylates and various copolymers and multipolymers of lower alkylacrylates and methacrylates.

The plasticizers which can be used here include, for example, dibutyl phthalate, dioctyl phthalate, polyethylene glycol, glycerol, etc.

The solvents which can be used here include, for example, methyl cellosolve, ethyl cellosolve, butyl cellosolve, methyl ethyl ketone, dioxane, acetone, cyclohexanone, cyclopentanone,



isobutyl alcohol, isopropyl alcohol, tetrahydrofuran, butylcarbitol acetate, dimethyl sulfoxide,  $\gamma$ -butyrolactone, bromobenzene, chlorobenzene, dibromobenzene, dichlorobenzene, bromobenzoic acid, chlorobenzoic acid and organic solvent mixtures containing at least one or more of the foregoing.

The organic dispersing agents which can be used here include anionic and nonionic surfactants, etc.

In the present invention, when the patterning by photolithography is effected, it is possible to use photosensitive fluorescent pastes respectively with an organic component containing a photosensitive compound and a fluorescent powder as essential ingredients.

It is preferable that the organic component used in the photosensitive fluorescent pastes contains 10 wt% or more of a photosensitive compound. More preferable is 25 wt% or more. The organic component containing a photosensitive compound contains at least one photosensitive ingredient selected from photosensitive polymers, photosensitive monomers and photosensitive oligomers, and furthermore, as required, also such additives as photopolymerization initiator, sensitizer and ultraviolet light absorber.

It is preferable that the amount of the organic component containing a photosensitive compound used in the present invention is 15 to 60 wt%. If less than 15 wt%, the pattern property is degraded due to insufficient sensitivity, and if

more than 60 wt%, the removal of the binder by burning is insufficient.

The fluorescent paste or photosensitive fluorescent paste consisting of these ingredients is usually prepared by mixing various ingredients such as a fluorescent powder, organic binder, ultraviolet light absorber, photosensitive polymer, photosensitive monomer, photopolymerization initiator, dispersing agent, plasticizer and solvent to achieve a predetermined composition, and homogeneously dispersing the mixture by a three-roller mill or kneader. As other methods, a dispersing agent dissolved in a solvent can be mixed with the other ingredients, or a fluorescent powder treated on the surfaces of its grains by a dispersing agent or ultraviolet light absorber can also be mixed with the other ingredients.

The glass substrate used in the present invention is not especially limited, and a general soda lime glass or a glass obtained by annealing a soda lime glass, or a glass with a high strain point (e.g., "PD-200" produced by Asahi Glass Co., Ltd.), etc. can be used. The size of the glass substrate is not especially limited, and a 1 to 5 mm thick glass can be used.

By forming fluorescent material layers on a glass substrate with electrodes and partitions formed on it, a board for a plasma display can be obtained. A substrate with a dielectric layer formed on it in addition to electrodes and partitions can also be used. The electrodes can be formed by

applying silver, aluminum, copper, gold, nickel, tin oxide or ITO, etc. by screen printing or using a photosensitive conductive paste.

The partitions can be formed as a grid or in stripes, but the present invention is especially effective when the partitions are formed in stripes. It is preferable that the pitch of the partitions is 100 to 500  $\mu\text{m}$ , and that the height of the partitions is 50 to 200  $\mu\text{m}$ .

Examples of forming the fluorescent material layers of the plasma display according to the present invention are described below, but the present invention is not limited thereto or thereby.

#### (1) Coating step

A glass substrate with an electrode layer and a partition layer formed on it (Fig. 1) is coated with fluorescent pastes of respective colors on the spaces formed between the respectively adjacent partitions and predetermined for the respective colors. For coating, a paste applicator having outlet holes with their length (L) and their diameter (D) satisfying the formula of  $L/D = 0.1$  to 600 is used, and the tips of the outlet holes (which can also be formed as nozzles or needles) are set at a height of 0.01 to 2 mm above the tops of the partitions (Fig. 4). In this state, the paste applicator is driven to travel at a constant speed in parallel to the striped partitions, for discharging the fluorescent pastes at a

constant rate for pouring them onto the spaces between the respectively adjacent partitions.

In this case, one paste applicator with one outlet hole or nozzle or needle can be used for discharging any of the three fluorescent pastes of R, G and B, for coating the spaces between adjacent partitions one by one. As a more efficient method, it is preferable to use a paste applicator with two or more outlet holes arranged on one straight line at certain coating intervals for one color, for simultaneously coating two or more spaces formed between adjacent partitions.

As a further more efficient method, two or more paste applicators each for respective colors can also be synchronized or interlocked to be driven for coating the panel on its full face.

If paste applicators with outlet holes or nozzles or needles as described above are used, the fluorescent pastes of respective R, G and B colors can be applied for coating in stripes by turns or simultaneously.

It is preferable that the fluorescent pastes used have a viscosity of 0.1 to 50 Pa·s and are discharged at a pressure of 50 to 1000 kPa.

The fluorescent materials of the plasma display must have a thickness of 10 to 50  $\mu\text{m}$  on the bottoms of the spaces between the respectively adjacent partitions and along the lateral sides (as a thickness at a half-height position of each

partition), and the coating thickness must be controlled by controlling the discharged amount of the fluorescent paste by the discharge pressure and the coating speed, considering the shrinkage after drying and burning depending on the fluorescent powder content of each fluorescent paste used.

## (2) Drying step

Coating is followed by drying. It is preferable to dry at 50 to 200°C for 5 to 60 minutes in a hot air oven or on a hot plate.

## (3) Burning step

Drying is followed by burning in a burning furnace. The burning atmosphere and temperature depend on the pastes and substrate used. The burning is effected in an atmosphere of air, nitrogen or hydrogen, etc. The burning temperature is 400 to 550°C. The burning furnace used can be a batch burning furnace or a belt type or roller-hearth type continuous burning furnace.

According to the above steps (1) to (3), a rear board for a plasma display panel with fluorescent material layers formed on the spaces between the respectively adjacent partitions on a glass substrate can be produced.

Furthermore, to remove the fluorescent materials formed on the tops of the partitions and other unnecessary portions than the partitions due to coating, photosensitive fluorescent pastes can be used for patterning by photolithography. In this

case, the coated substrate is exposed through a photomask, to make the pastes of the exposed portions soluble or insoluble in the developer, for removing the unnecessary portions by development. In this case, the burning step (3) is preceded by exposure step (4) and development step (5).

#### (4) Exposure step

As in ordinary photolithography, it is general to effect mask exposure using a photomask. Either a negative or positive mask is selected, depending on the photosensitive organic component used. As another method, a laser beam, etc. can also be used for direct drawing without using any photomask. As the exposure machine, a stepper exposure machine or proximity exposure machine, etc. can be used.

For exposing a large area, after the substrate such as a glass substrate has been coated with photosensitive pastes, the substrate can be carried forward during exposure, to expose a large area by an exposure machine with a small effective exposure area.

The active light used in this case can be visible light, near ultraviolet light, ultraviolet light, electron beam, X ray or laser beam, etc. Among them, ultraviolet light is preferable. The light source can be, for example, a low pressure mercury lamp, high pressure mercury lamp, extra-high pressure mercury lamp, halogen lamp or germicidal lamp, etc. Among them, an extra-high pressure mercury lamp is suitable.

If a photomask is used, the design of the pattern width is important. Usually, a width equal to the space obtained by subtracting the partition width from the partition pitch is used, but considering the accuracy of alignment and the light scattering at the time of exposure, a photomask with a pattern width more narrow than the space by 0 to 30 mm can also be used.

#### (5) Development step

After completion of exposure, a developer is used for development. In this case, immersion, spray or brushing is used.

The developer can be an organic solvent which allows the organic component in the photosensitive pastes to be dissolved. The organic solvent can also contain water to such an extent that the dissolving power may not be lost. If a compound with an acidic group such as a carboxyl group exists in the photosensitive paste, an alkali aqueous solution can be used for development. The alkali aqueous solution can be an alkali metal aqueous solution such as sodium hydroxide or calcium hydroxide aqueous solution, but the use of an organic alkali aqueous solution is preferable since the alkali component can be easily removed at the time of burning.

The organic alkali can be an amine compound. The organic alkalis which can be used here include tetramethylammonium hydroxide, trimethylbenzylammonium hydroxide, monoethanolamine, diethanolamine, etc. The concentration of

the alkali aqueous solution is usually 0.01 to 10 wt%, preferably 0.1 to 5 wt%. If the alkali concentration is too low, the non-exposed portions cannot be removed, and if too high, the pattern may peel to erode the exposed portions. In view of process control, it is preferable that the development temperature is 20 to 50°C.

In addition to the above steps, a heating step of 50 to 300°C can also be used for drying or preliminary reaction.

If the rear board for a plasma display panel obtained according to the above steps (Fig. 3) is sealed with the glass substrates on the front and rear faces, and a rare gas such as helium, neon or xenon is introduced into the sealed housing, then the panel of a plasma display can be produced. Furthermore, if a driver IC is mounted, a plasma display can be produced.

#### [Examples]

The present invention is described below concretely in reference to examples, but is not limited thereto or thereby. In the examples, each concentration (%) is wt% unless otherwise stated.

#### Example 1

Fluorescent pastes respectively consisting of 45 g of a fluorescent powder, 25 g of a binder polymer (methyl methacrylate-methacrylic acid-styrene copolymer), 28 g of a solvent ( $\gamma$ -butyrolactone) and 2 g of a dispersing agent were prepared. The fluorescent powders used were red (Y, Gd, Eu)BO<sub>3</sub>



(cumulative average grain size  $2.7\ \mu\text{m}$ , specific surface area  $3.1\ \text{m}^2/\text{cc}$ ), green  $(\text{Zn}, \text{Mn})_2\text{SiO}_4$  (cumulative average grain size  $3.6\ \mu\text{m}$ , specific surface area  $2.5\ \text{m}^2/\text{cc}$ ) and blue  $(\text{Ba}, \text{Eu})\text{MgAl}_{10}\text{O}_{17}$  (cumulative average grain size  $3.7\ \mu\text{m}$ , specific surface area  $2.3\ \text{m}^2/\text{cc}$ ). At first the respective organic ingredients were dissolved by heating at  $60^\circ\text{C}$ , and then a fluorescent powder was added. The mixture was kneaded by a kneader, to prepare a paste. The respective pastes were  $9\ \text{Pa}\cdot\text{s}$  in viscosity.

A glass substrate with nine hundred and sixty one  $150\ \mu\text{m}$  high  $60\ \mu\text{m}$  wide partitions formed at a pitch of  $220\ \mu\text{m}$  on it was coated with the respective pastes of red, green and blue in stripes.

For coating, paste applicators respectively having five  $3\ \text{mm}$  long needles with an inner diameter of  $150\ \mu\text{m}$  pressed in at the tip at a pitch of  $660\ \mu\text{m}$  in one line ( $L/D = 20$ ) were used. One paste applicator each was used for the fluorescent pastes of red, blue and green. The distance between the tips of the needles and the tops of the partitions was set at  $80\ \mu\text{m}$ . The discharge pressure was set at  $300\ \text{kPa}$  by a dispenser. The paste applicators were driven to travel at a constant speed of  $20\ \text{mm/s}$  in parallel to the partitions, while the fluorescent pastes were discharged at a constant rate for coating five spaces between adjacent partitions respectively simultaneously. At first, the red fluorescent paste was applied to predetermined five

spaces between adjacent partitions simultaneously. At the position where the coating of five spaces was completed, the paste applicator was moved in the direction perpendicular to the partitions by 3300  $\mu\text{m}$ . Then, it was driven to travel similarly in the reverse direction for coating five spaces between adjacent partitions. This was repeated to coat predetermined 320 spaces with the red fluorescent material. After completion of coating with the red fluorescent material, it was dried at 80°C for 40 minutes with the coated side turned upward. Then, the blue fluorescent paste was similarly applied to the 320 spaces adjacent to those coated with the red fluorescent paste and dried. Furthermore, the green fluorescent paste was similarly applied to the 320 spaces adjacent to those coated with the blue fluorescent paste and dried. The obtained glass substrate was burned at 500°C for 30 minutes.

The thicknesses of the fluorescent material layers formed along the lateral sides and on the bottoms of the spaces were observed by an electron microscope. It was found that the fluorescent materials of the respective colors were formed with a thickness of  $20 \pm 5 \mu\text{m}$  along the lateral sides and with a thickness of  $20 \pm 5 \mu\text{m}$  on the bottoms of the spaces in stripes.

Example 2

Fluorescent pastes respectively consisting of 20 g of a fluorescent powder, 5 g of a binder polymer (ethyl cellulose)

and 75 g of a solvent (terpineol) were prepared. The fluorescent powders used were the same red (Y, Gd, Eu)BO<sub>3</sub>, green (Zn, Mn)<sub>2</sub>SiO<sub>4</sub> and blue (Ba, Eu)MgAl<sub>10</sub>O<sub>17</sub> as used in Example 1. At first the respective organic ingredients were dissolved by heating at 60°C, and then a fluorescent powder was added. The mixture was kneaded by a kneader, to prepare a paste. The respective pastes were 25 Pa·s in viscosity.

A glass substrate with nine hundred and sixty one 150 μm high 60 μm wide partitions formed at a pitch of 430 μm on it was coated with the respective pastes of red, green and blue in stripes.

For coating, paste applicators respectively having twenty 3 mm long needles with an inner diameter of 300 μm pressed in at the tip at a pitch of 1290 μm in one line (L/D = 10) were used. One paste applicator each was used for the fluorescent pastes of red, blue and green. The distance between the tips of the needles and the tops of the partitions was set at 100 μm. The discharge pressure was set at 200 kPa by a dispenser. The paste applicators were driven to travel at a constant speed of 15 mm/s in parallel to the partitions, while the fluorescent pastes were discharged at a constant rate for coating twenty spaces between adjacent partitions respectively simultaneously. At first, the red fluorescent paste was applied to predetermined twenty spaces between adjacent partitions simultaneously. At the position where the coating

of twenty spaces was completed, the paste applicator was moved in the direction perpendicular to the partitions by 25.8 mm. Then, it was driven to travel similarly in the reverse direction for coating twenty spaces between adjacent partitions. This was repeated to coat predetermined 320 spaces with the red fluorescent material. After completion of coating with the red fluorescent material, it was dried at 80°C for 40 minutes with the coated side turned upward. Then, the blue fluorescent paste was similarly applied to the 320 spaces adjacent to those coated with the red fluorescent paste and dried. Furthermore, the green fluorescent paste was similarly applied to the 320 spaces adjacent to those coated with the blue fluorescent paste and dried. The obtained glass substrate was burned at 400°C for 30 minutes.

The thicknesses of the fluorescent material layers formed along the lateral sides and on the bottoms of the spaces were observed by an electron microscope. It was found that the fluorescent materials of the respective colors were formed with a thickness of  $20 \pm 5 \mu\text{m}$  along the lateral sides and with a thickness of  $20 \pm 5 \mu\text{m}$  on the bottoms of the spaces in stripes.

### Example 3

Fluorescent pastes respectively consisting of 45 g of a fluorescent powder, 23 g of a binder polymer (polyvinyl alcohol), 30 g of a solvent (water) and 2 g of a dispersing agent were prepared. The fluorescent powders used were the same red (Y,

Gd, Eu)BO<sub>3</sub>, green (Zn, Mn)<sub>2</sub>SiO<sub>4</sub> and blue (Ba, Eu)MgAl<sub>10</sub>O<sub>17</sub> as used in Example 1. At first the respective organic ingredients were dissolved by heating at 60°C, and then a fluorescent powder was added. The mixture was kneaded by a kneader, to prepare a paste. The respective pastes were 3 Pa·s in viscosity.

A glass substrate with nine hundred and sixty one 150 µm high 60 µm wide partitions formed at a pitch of 220 µm on it was coated with the respective pastes of red, green and blue in stripes.

For coating, paste applicators respectively having five 15 mm needles with an inner diameter of 150 µm pressed in at the tip at a pitch of 660 µm in one line (L/D = 100) were used. Four paste applicators each were used for the fluorescent pastes of red, blue and green. Four paste applicators with nozzles were arranged every 52.8 mm in the direction perpendicular to the partitions, and synchronized to be driven for traveling simultaneously at the same speed in the same direction. The distance between the tips of the nozzles and the tops of the partitions was set at 80 µm. The discharge pressure was set at 400 kPa by a dispenser. The paste applicators were driven to travel at a constant speed of 20 mm/s in parallel to the partitions, while the fluorescent pastes were discharged at a constant rate for coating twenty spaces between adjacent partitions respectively simultaneously. At first, the red fluorescent paste was applied to predetermined twenty spaces

between adjacent partitions simultaneously. At the position where the coating of twenty spaces was completed, the four paste applicators were moved in the direction perpendicular to the partitions by 3300  $\mu\text{m}$  respectively. Then, they were driven to travel similarly in the reverse direction for coating twenty spaces between adjacent partitions. This was repeated to coat predetermined 320 spaces with the red fluorescent material. After completion of coating with the red fluorescent material, it was dried at 80°C for 40 minutes with the coated side turned upward. Then, the blue fluorescent paste was similarly applied to the 320 spaces adjacent to those coated with the red fluorescent paste and dried. Furthermore, the green fluorescent paste was similarly applied to the 320 spaces adjacent to those coated with the blue fluorescent paste and dried. The obtained glass substrate was burned at 500°C for 30 minutes.

The thicknesses of the fluorescent material layers formed along the lateral sides and on the bottoms of the spaces were observed by an electron microscope. It was found that the fluorescent materials of the respective colors were formed with a thickness of  $20 \pm 5 \mu\text{m}$  along the lateral sides and with a thickness of  $20 \pm 5 \mu\text{m}$  on the bottoms of the spaces in stripes.

Example 4

Fluorescent pastes respectively consisting of 38 g of a fluorescent powder, 16 g of a binder polymer (methyl

methacrylate-methacrylic acid-styrene copolymer), 44 g of a solvent ( $\gamma$ -butyrolactone) and 2 g of a dispersing agent were prepared. The fluorescent powders used were the same red (Y, Gd, Eu)BO<sub>3</sub>, green (Zn, Mn)<sub>2</sub>SiO<sub>4</sub> and blue (Ba, Eu)MgAl<sub>10</sub>O<sub>17</sub> as used in Example 1. At first the respective organic ingredients were dissolved by heating at 60°C, and then a fluorescent powder was added. The mixture was kneaded by a kneader, to prepare a paste. The respective pastes were 1 Pa·s in viscosity.

A glass substrate with nine hundred and sixty one 150  $\mu$ m high 60  $\mu$ m wide partitions formed at a pitch of 220  $\mu$ m on it was coated with the respective pastes of red, green and blue in stripes.

For coating, paste applicators respectively having five 30 mm needles with an inner diameter of 150  $\mu$ m pressed in at the tip at a pitch of 660  $\mu$ m in one line ( $L/D = 200$ ) were used. Four paste applicators each were used for the fluorescent pastes of red, blue and green. Four paste applicators with nozzles were arranged every 52.8 mm in the direction perpendicular to the partitions, and synchronized to be driven for traveling simultaneously at the same speed in the same direction. The distance between the tips of the nozzles and the tops of the partitions was set at 100  $\mu$ m. The discharge pressure was set at 300 kPa by a dispenser. The paste applicators were driven to travel at a constant speed of 25 mm/s in parallel to the partitions, while the fluorescent pastes were discharged at a

constant rate for coating twenty spaces between adjacent partitions respectively simultaneously. At first, the red fluorescent paste was applied to predetermined twenty spaces between adjacent partitions simultaneously. At the position where the coating of twenty spaces was completed, the four paste applicators were moved in the direction perpendicular to the partitions by 3300  $\mu\text{m}$  respectively. Then, they were driven to travel similarly in the reverse direction for coating twenty spaces between adjacent partitions. This was repeated to coat predetermined 320 spaces with the red fluorescent material. After completion of coating with the red fluorescent material, it was dried at 80°C for 40 minutes with the coated side turned upward. Then, the blue fluorescent paste was similarly applied to the 320 spaces adjacent to those coated with the red fluorescent paste and dried. Furthermore, the green fluorescent paste was similarly applied to the 320 spaces adjacent to those coated with the blue fluorescent paste and dried. The obtained glass substrate was burned at 500°C for 30 minutes.

The thicknesses of the fluorescent material layers formed along the lateral sides and on the bottoms of the spaces were observed by an electron microscope. It was found that the fluorescent materials of the respective colors were formed with a thickness of  $20 \pm 5 \mu\text{m}$  along the lateral sides and with a thickness of  $20 \pm 5 \mu\text{m}$  on the bottoms of the spaces in stripes.



#### Example 5

Fluorescent pastes respectively consisting of 45 g of a fluorescent powder, 22 g of a binder polymer (methyl methacrylate-methacrylic acid-styrene copolymer), 12 g of trimethylolpropane triacrylate, 18 g of a solvent ( $\gamma$ -butyrolactone), 2 g of a dispersing agent, 0.05 g of a benzophenone dye and a photopolymerization initiator ("Irgacure" 907 produced by Ciba Geigy) were prepared. The fluorescent powders used were the same red (Y, Gd, Eu)BO<sub>3</sub>, green (Zn, Mn)<sub>2</sub>SiO<sub>4</sub> and blue (Ba, Eu)MgAl<sub>10</sub>O<sub>17</sub> as used in Example 1. At first the respective organic ingredients were dissolved by heating at 60°C, and then a fluorescent powder was added. The mixture was kneaded by a kneader, to prepare a paste. The respective pastes were 10 Pa·s in viscosity.

A glass substrate with nine hundred and sixty one 120  $\mu$ m high 30  $\mu$ m wide partitions formed at a pitch of 140  $\mu$ m on it was coated with the respective pastes of red, green and blue in stripes.

For coating, paste applicators respectively having one 0.1 mm long nozzle with an inner diameter of 100  $\mu$ m ( $L/D = 1$ ) were used. Four paste applicators each were used for the fluorescent pastes of red, blue and green. Four paste applicators with nozzles were arranged every 33.6 mm in the direction perpendicular to the partitions, and synchronized to be driven for traveling simultaneously at the same speed in the same

direction. The distance between the tips of the nozzles and the tops of the partitions was set at 50  $\mu\text{m}$ . The discharge pressure was set at 300 kPa by a dispenser. The paste applicators were driven to travel at a constant speed of 20 mm/s in parallel to the partitions, while the fluorescent pastes were discharged at a constant rate for coating four spaces between adjacent partitions respectively simultaneously. At first, the red fluorescent paste was applied to predetermined four spaces between adjacent partitions simultaneously. At the position where the coating of four spaces was completed, the four paste applicators were moved in the direction perpendicular to the partitions by 420  $\mu\text{m}$  respectively. Then, they were driven to travel similarly in the reverse direction for coating four spaces between adjacent partitions. This was repeated to coat predetermined 320 spaces with the red fluorescent material. After completion of coating with the red fluorescent material, it was dried at 80°C for 40 minutes with the coated side turned upward. Then, the blue fluorescent paste was similarly applied to the 320 spaces adjacent to those coated with the red fluorescent paste and dried. Furthermore, the green fluorescent paste was similarly applied to the 320 spaces adjacent to those coated with the blue fluorescent paste and dried.

Then, a negative photomask with 40  $\mu\text{m}$  wide lines formed at a pitch of 140  $\mu\text{m}$  was aligned, and the coated substrate was

exposed, developed by 0.5% sodium carbonate aqueous solution and burned at 500°C for 30 minutes.

The thicknesses of the fluorescent material layers formed along the lateral sides and on the bottoms of the spaces were observed by an electron microscope. It was found that the fluorescent materials of the respective colors were formed with a thickness of  $20 \pm 5 \mu\text{m}$  along the lateral sides and with a thickness of  $25 \pm 5 \mu\text{m}$  on the bottoms of the spaces in stripes.

#### Example 6

A glass substrate with nine hundred and sixty one  $100 \mu\text{m}$  high and  $30 \mu\text{m}$  wide partitions formed at a pitch of  $130 \mu\text{m}$  on it was coated with the same pastes of red, green and blue as used in Example 4 in stripes.

For coating, paste applicators respectively having five 25 mm long needles with an inner diameter of  $100 \mu\text{m}$  pressed in at the tip at a pitch of  $390 \mu\text{m}$  (arranged alternately zigzag in two lines at a pitch of  $560 \mu\text{m}$  in the direction parallel to the partitions) ( $L/D = 250$ ) were used. Two paste applicators each were used for the fluorescent pastes of red, blue and green. Two paste applicators were arranged every 62.4 mm in the direction perpendicular to the partitions and synchronized to be driven for traveling simultaneously at the same speed in the same direction. The distance between the tips of the needles and the tops of the partitions was set at  $50 \mu\text{m}$ . The discharge pressure was set at 400 kPa by a dispenser. The paste

applicators were driven to travel in parallel to the partitions at a constant speed of 15 mm/s, while the fluorescent pastes were discharged at a constant rate for coating the spaces between the respectively adjacent partitions. At first, the red fluorescent paste was applied to predetermined ten spaces between adjacent partitions simultaneously. At the position where the coating of 10 spaces was completed, the two paste applicators were moved in the direction perpendicular to the partitions by 1950  $\mu\text{m}$  respectively. Then, the paste applicators were driven to travel similarly in the reverse direction for coating ten spaces between adjacent partitions. This was repeated to coat predetermined 320 spaces with the red fluorescent material. After completion of coating with the red fluorescent material, it was dried at 80°C for 40 minutes with the coated side turned upward. Then, the blue fluorescent paste was applied similarly to the 320 spaces adjacent to those coated with the red fluorescent paste and dried. Furthermore, the green fluorescent paste was applied similarly to the 320 spaces adjacent to those coated with the blue fluorescent paste and dried. The obtained glass substrate was burned at 500°C for 30 minutes.

The thicknesses of the fluorescent material layers formed along the lateral sides and on the bottoms of the spaces were observed by an electron microscope. It was found that the fluorescent materials of the respective colors were formed with

a thickness of  $20 \pm 5 \mu\text{m}$  along the lateral sides and with a thickness of  $20 \pm 5 \mu\text{m}$  on the bottoms of the spaces in stripes.

[Effects of the invention]

The present invention allows fluorescent material layers of a plasma display to be formed simply and easily. Furthermore, fluorescent material layers suitable for a highly precise plasma display can be formed.

[Brief description of the drawings]

[Fig. 1] A typical view showing a glass substrate with partitions formed on it, used in the present invention.

[Fig. 2] A typical view showing a plasma display panel coated with fluorescent material layers according to the method of the present invention.

[Fig. 3] A typical view showing a burned plasma display panel of the present invention.

[Fig. 4] A drawing typically showing an example of the method of the present invention applied to a glass substrate with partitions formed.

[Fig. 5] A schematic sectional view typically showing an example of the paste applicator of the present invention.

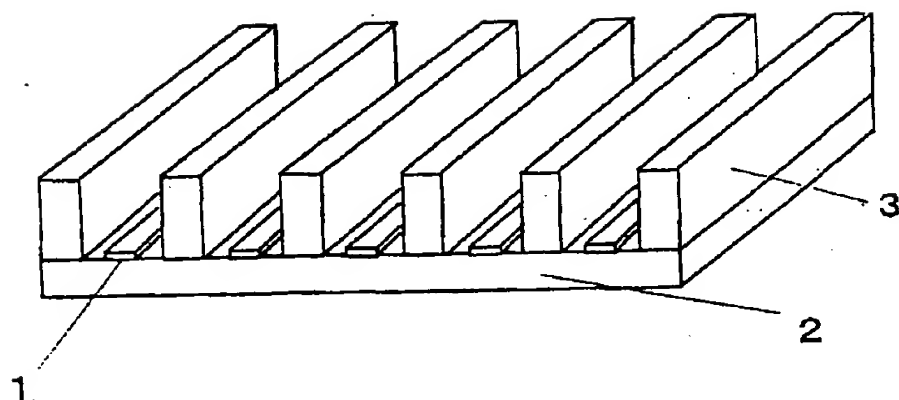
[Fig. 6] A schematic sectional view typically showing an example of the paste applicator with nozzles of the present invention.

[Fig. 7] A schematic sectional view typically showing an example of the paste applicator with needles of the present invention.

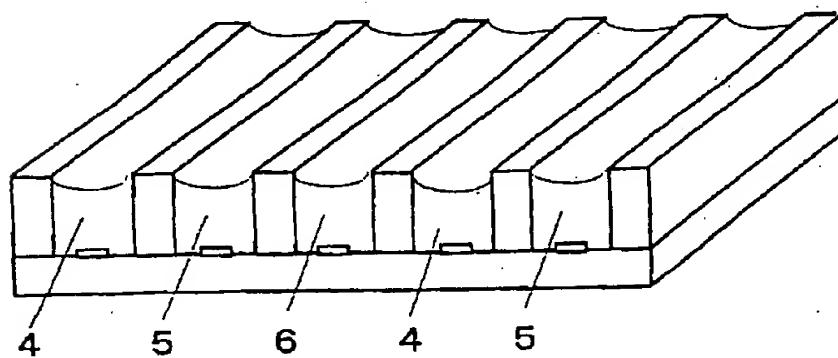
[Meanings of symbols]

- 1 : electrode
- 2 : glass substrate
- 3 : partition
- 4 : red fluorescent material layer
- 5 : blue fluorescent material layer
- 6 : green fluorescent material layer
- 7 : needle
- 8 : fluorescent paste
- 9 : distance between tip of outlet hole and top of partition
- 10 : paste applicator with outlet holes
- 11 : paste applicator with nozzles
- 12 : paste applicator with needles
- 13 : length of outlet hole (L)
- 14 : diameter of outlet hole (D)

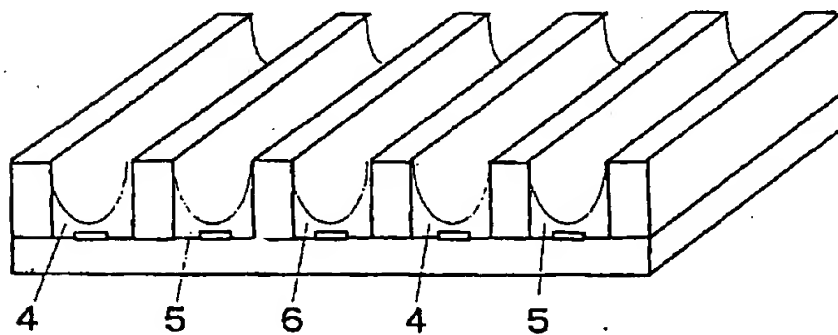
【Fig. 1】



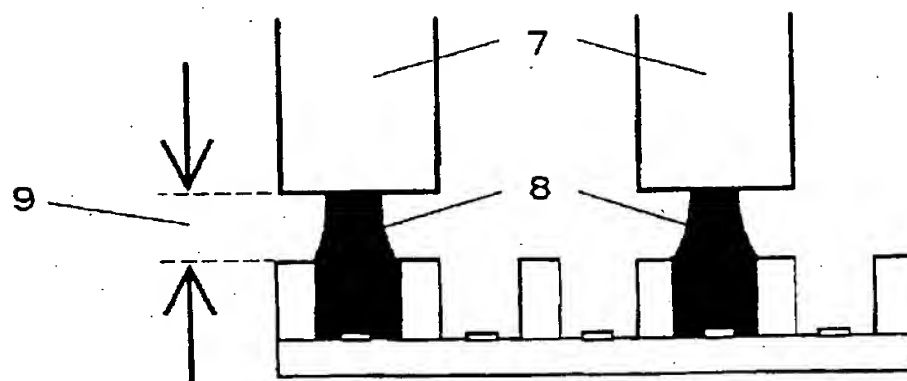
【Fig. 2】



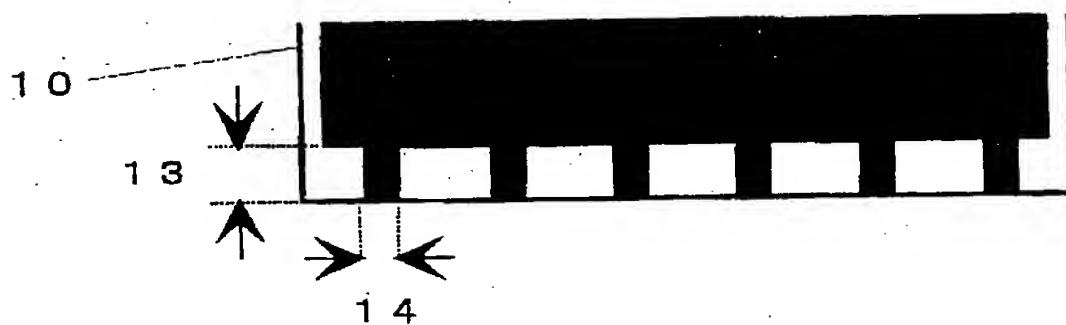
【Fig. 3】



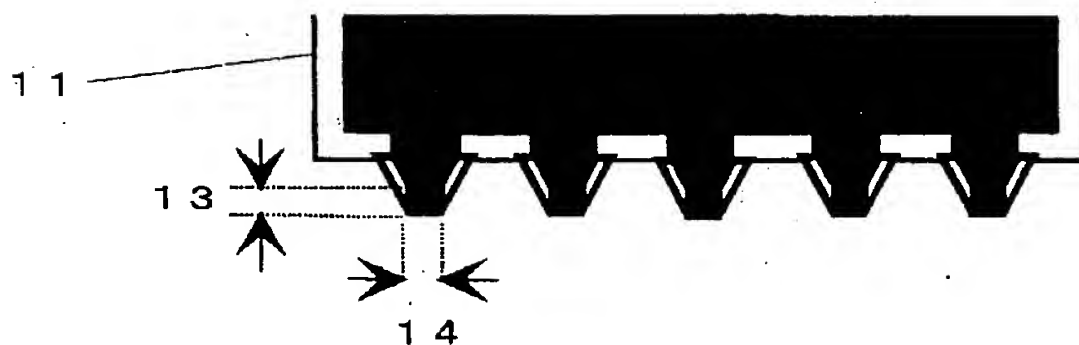
【Fig. 4】



【Fig. 5】

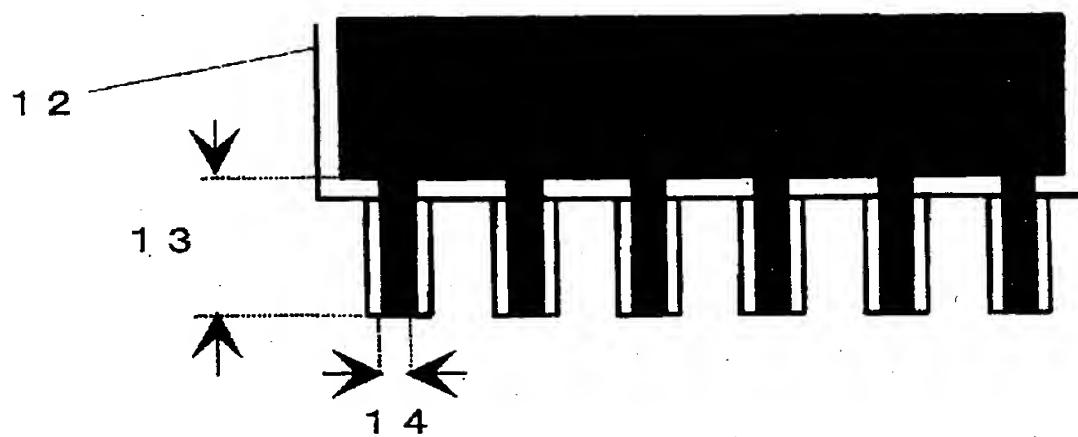


【Fig. 6】





【Fig. 7】



[Title of the document] Abstract

[Abstract]

[Problem] To provide a method for producing a plasma display panel which allows fluorescent material layers to be simply formed.

[Solving means] Three fluorescent pastes respectively containing any of red, green and blue fluorescent powders are applied to the spaces between the respectively adjacent partitions predetermined for the respective colors on a glass substrate, and burned to form fluorescent material layers. In this case, the object can be achieved by a method of producing a plasma display panel; characterized in that a paste applicator with outlet holes or nozzles or needles is used for coating.

[Selected drawing] Nil